ANALOG INTERFEROMETRIC MODULATOR DEVICE WITH ELECTROSTATIC ACTUATION AND RELEASE

BACKGROUND

[0001] 1. Field

[0002] The invention relates to microelectromechanical system devices and in particular to analog, digital, and/or optical devices utilizing a microelectromechanical system.

[0003] 2. Description of the Related Art

[0004] Microelectromechanical systems (MEMS) include micro mechanical elements, actuators, and electronics. Micromechanical elements may be created using deposition, etching, and or other micromachining processes that etch away parts of substrates and/or deposited material layers or that add layers to form electrical and electromechanical devices. One type of MEMS device is called an interferometric modulator. As used herein, the term interferometric modulator or interferometric light modulator refers to a device that selectively absorbs and/or reflects light using the principles of optical interference. In certain embodiments, an interferometric modulator may comprise a pair of conductive plates, one or both of which may be transparent and/or reflective in whole or part and capable of relative motion upon application of an appropriate electrical signal. In a particular embodiment, one plate may comprise a stationary layer deposited on a substrate and the other plate may comprise a metallic membrane separated from the stationary layer by an air gap. As described herein in more detail, the position of one plate in relation to another can change the optical interference of light incident on the interferometric modulator. Such devices have a wide range of applications, and it would be beneficial in the art to utilize and/or modify the characteristics of these types of devices so that their features can be exploited in improving existing products and creating new products that have not yet been developed.

SUMMARY

[0005] One embodiment of a microelectromechanical system (MEMS) device comprises a first electrode, a second electrode electrically insulated from the first electrode, and a third electrode electrically insulated from the first electrode and the second electrode. The MEMS device also comprises a support structure which separates the first electrode from the second electrode. The MEMS device further comprises a reflective element located and movable between a first position and a second position. The reflective element is in contact with a portion of the device when in the first position and is not in contact with the portion of the device when in the second position. An adhesive force is generated between the reflective element and the portion when the reflective element is in the first position. Voltages applied to the first electrode, the second electrode, and the third electrode at least partially reduce or counteract the adhesive force.

[0006] Another embodiment of a microelectromechanical system (MEMS) device comprises a first means for conducting electricity, a second means for conducting electricity, the second conducting means electrically insulated from the first conducting means, and a third means for conducting electricity, the third conducting means electrically insulated from the first conducting means and the second conducting means. The MEMS device further comprises means for separating the first conducting means from the second conducting means. The MEMS device further comprises means for reflecting light, the reflecting means located and movable between a first position and a second position. The reflecting means is in contact with a portion of the device when in the first position and is not in contact with the portion of the device when in the second position. An adhesive force is generated between the reflecting means and the portion when the reflecting means is in the first position. Voltages applied to the first conducting means, the second conducting means, and the third conducting means at least partially reduce or counteract the adhesive force.

[0007] An embodiment of a method of operating a microelectromechanical system (MEMS) device comprises providing a MEMS device that comprises a first electrode, a second electrode electrically insulated from the first electrode, and a third electrode electrically insulated from the first electrode and the second electrode. The MEMS device further comprises a support structure which separates the first electrode from the second electrode. The MEMS device further comprises a reflective element located and movable between a first position and a second position. The reflective element is in contact with a portion of the device when in the first position and is not in contact with the portion of the device when in the second position. An adhesive force is generated between the reflective element and the portion when the reflective element is in the first position. The method further comprises applying voltages to the first electrode, the second electrode, and the third electrode to at least partially reduce or counteract the adhesive force.

[0008] An embodiment of a method of manufacturing a microelectromechanical system (MEMS) device comprises forming a first reflective layer on a substrate, forming a sacrificial layer over the first reflective layer, removing a portion of the sacrificial layer to form an opening, and filling the opening with a dielectric material to form a post. The method further comprises forming a second reflective layer over the sacrificial layer, removing a portion of the second reflective layer and a portion of the post to form a hole, filling the hole with a conductive material to form an electrode, and removing the sacrificial layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is an isometric view depicting a portion of one embodiment of an interferometric modulator display in which a movable reflective layer of a first interferometric modulator is in a relaxed position and a movable reflective layer of a second interferometric modulator is in an actuated position.

[0010] FIG. **2** is a system block diagram illustrating one embodiment of an electronic device incorporating a 3×3 interferometric modulator display.

[0011] FIG. **3** is a diagram of movable mirror position versus applied voltage for one exemplary embodiment of an interferometric modulator of FIG. **1**.

[0012] FIG. **4** is an illustration of a set of row and column voltages that may be used to drive an interferometric modulator display.

[0013] FIG. **5**A illustrates one exemplary frame of display data in the 3×3 interferometric modulator display of FIG. **2**.